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(54) **METHOD FOR BALANCING ROTATING ASSEMBLY OF GAS TURBINE ENGINE**

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F01D 5/02 (2006.01)
F01D 9/04 (2006.01)

(52) **U.S. Cl.**

CPC ***F01D 5/027*** (2013.01); ***F01D 9/042*** (2013.01); *F05D 2230/80* (2013.01); *F05D 2260/15* (2013.01); *F05D 2260/34* (2013.01); *Y10T 29/49233* (2015.01)

(58) **Field of Classification Search**

CPC F01D 5/027; F01D 9/042
USPC .... 415/201, 209.3, 155, 160, 161; 416/144, 204 R, 206, 207, 208, 500; 700/279

See application file for complete search history.

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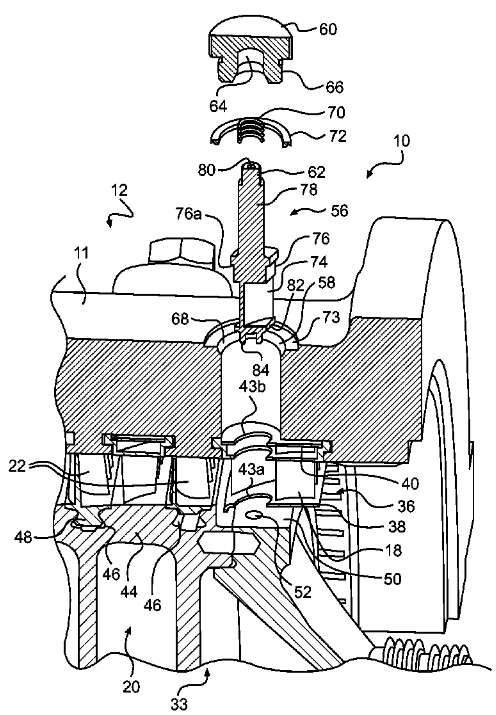
(57) **ABSTRACT**

A method for balancing a rotating assembly of a gas turbine engine includes removing a stator vane from a section of the gas turbine engine. Removing the stator vane provides access to a rotating assembly of the gas turbine engine. The method further includes at least one of adding, removing, and repositioning a weight with respect to the rotating assembly via access to the rotating assembly provided by removing the stator vane.

18 Claims, 7 Drawing Sheets



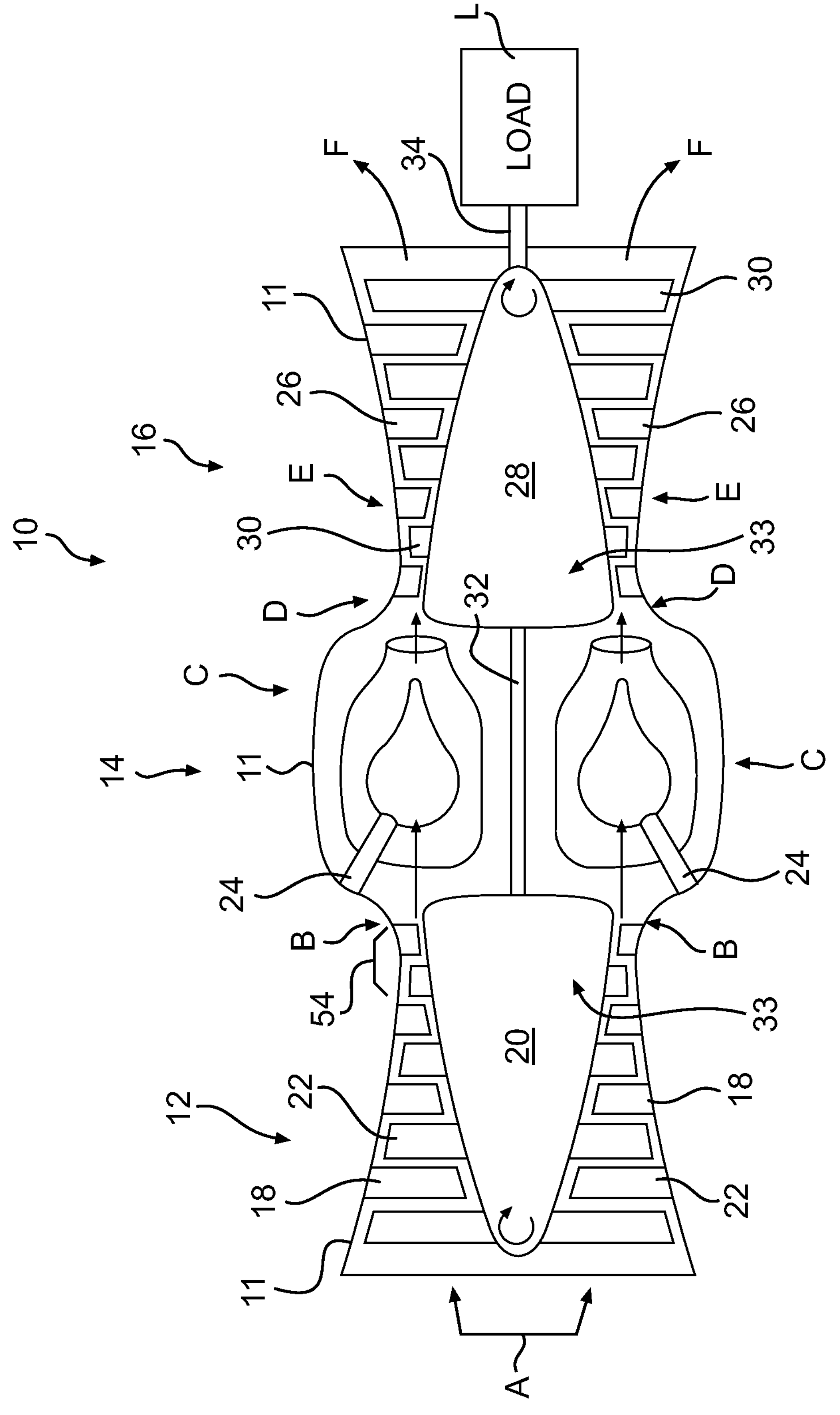


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FIG. 1

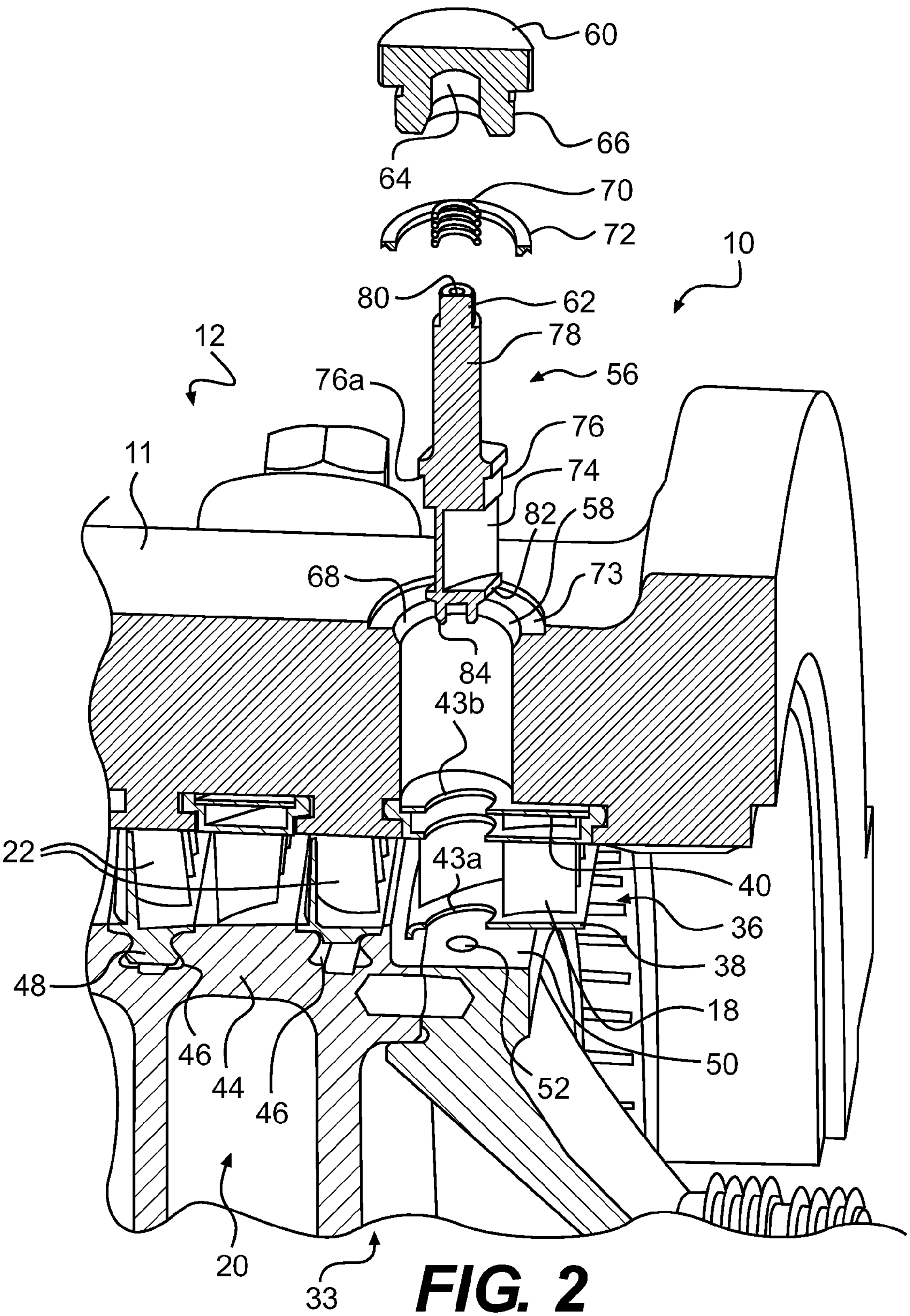

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FIG. 2

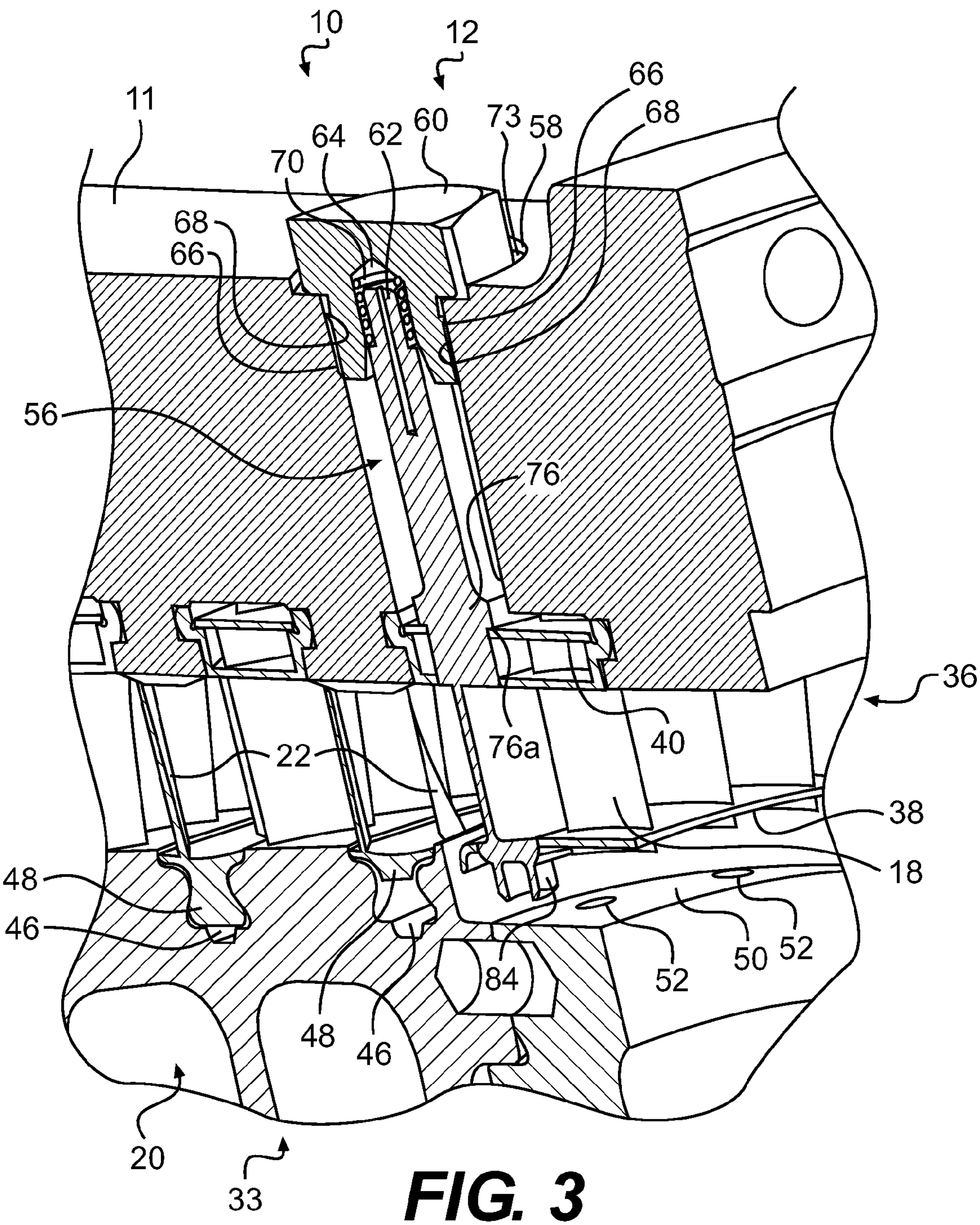
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FIG. 3

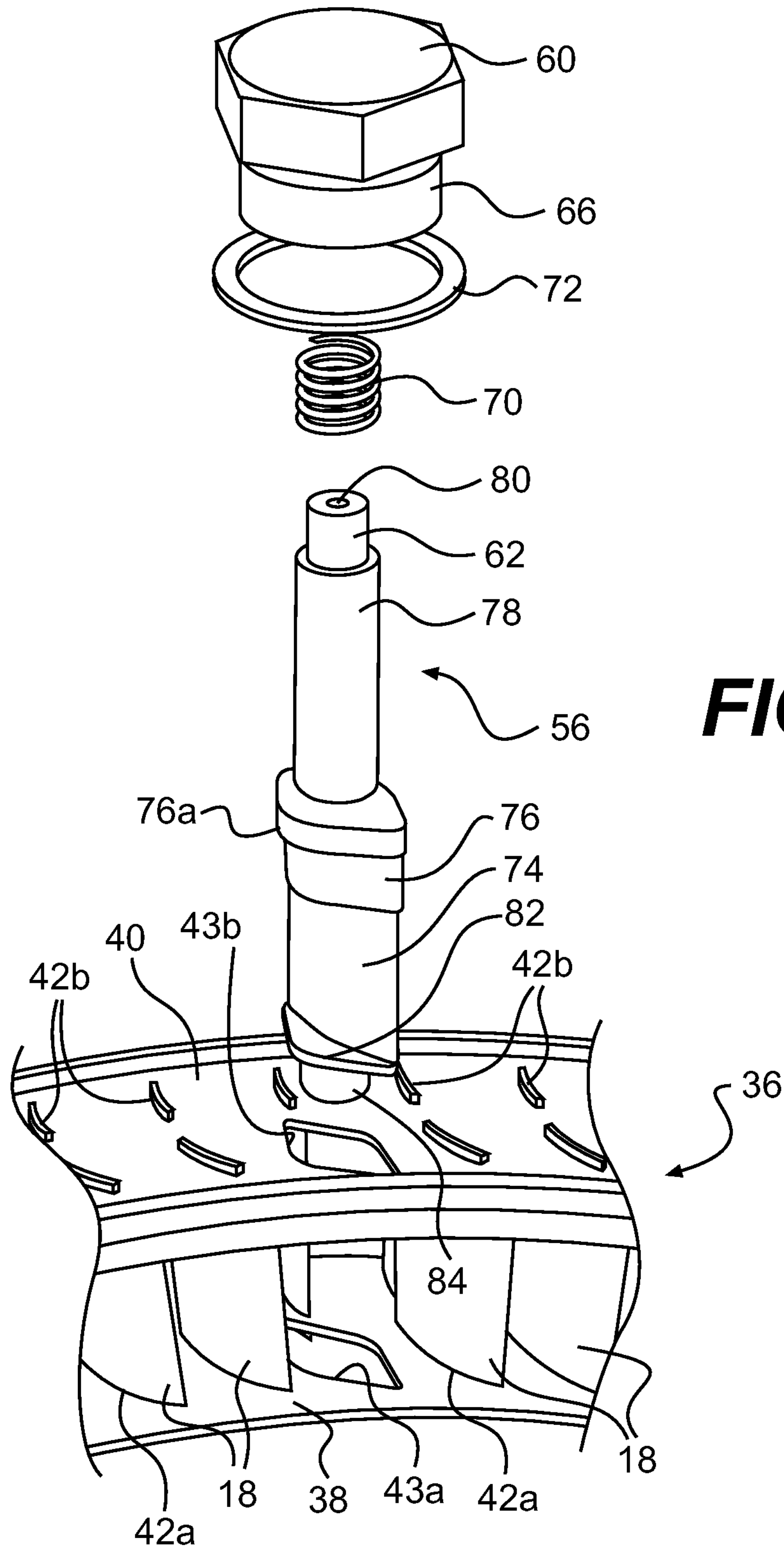
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FIG. 4

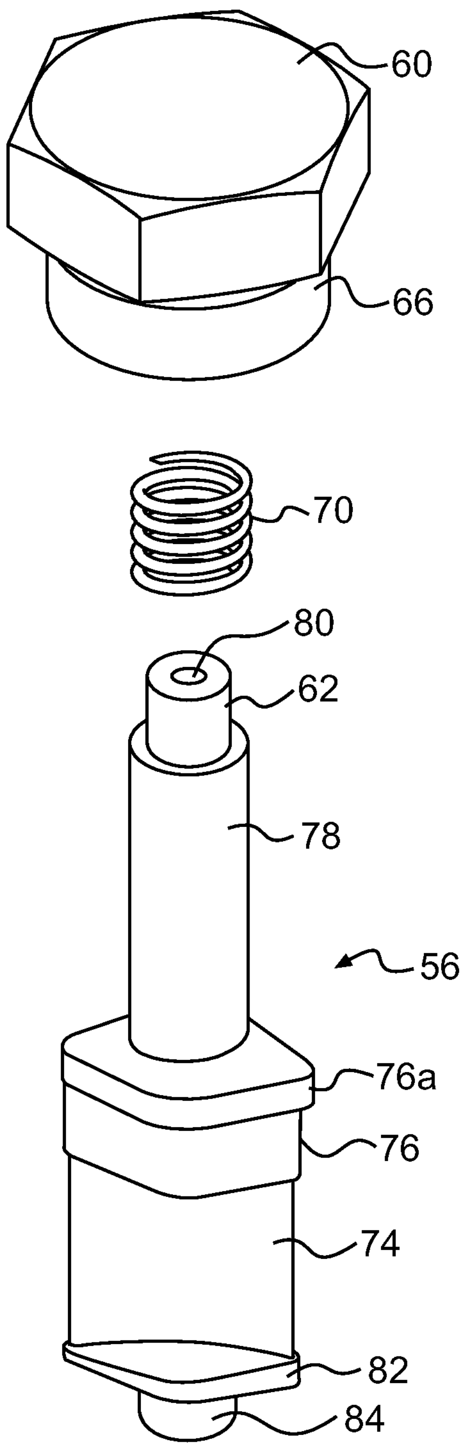

FIG. 5

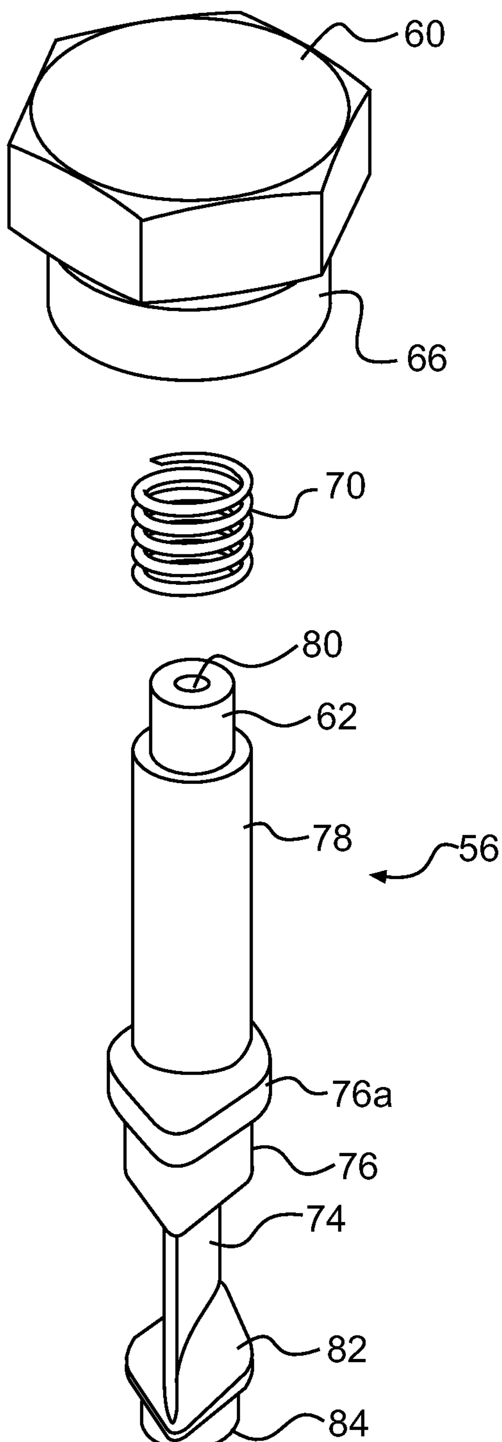

FIG. 6

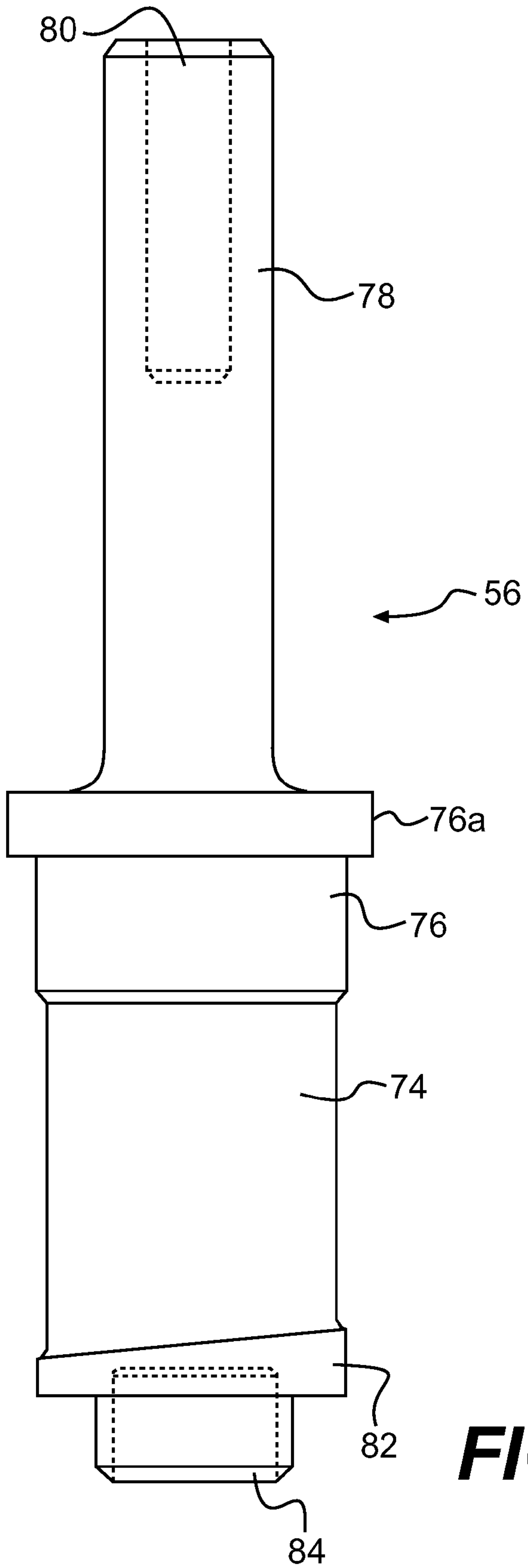

FIG. 7

METHOD FOR BALANCING ROTATING ASSEMBLY OF GAS TURBINE ENGINE

TECHNICAL FIELD

The present disclosure relates generally to a method for balancing a rotating assembly of a gas turbine engine (GTE) and, more particularly, to a method for balancing the rotating assembly of a GTE including removing a stator vane from the GTE.

BACKGROUND

GTEs convert the potential energy associated with air and fuel into energy primarily in the form of mechanical rotation and heat. A conventional GTE may include a compressor assembly, a combustor assembly, and a turbine assembly. During operation, air is drawn into the compressor assembly, where it is compressed and supplied to the combustor assembly. The combustor assembly supplies fuel to the compressed air and ignites the compressed air and fuel, resulting in combustion, which increases the energy associated with the compressed air. The combustion products are supplied to the turbine assembly, where expansion of the combustion products through the turbine assembly causes a turbine rotor to rotate. A compressor rotor of the compressor assembly and the turbine rotor may be coupled to one another via a shaft, such that rotation of the turbine rotor causes rotation of the compressor rotor. The turbine rotor may also be coupled to one or more systems that use the rotational energy and/or thermal energy from the turbine assembly. For example, a GTE may be used to supply power to machines, such as airplanes, locomotives, boats, ships, trucks, automobiles, electric generators, pumps, or other machines configured to perform work.

During operation, an assembly including the compressor and turbine rotors may rotate at 10,000 or more revolutions per minute, and thus, it may be desirable to balance the rotating assembly in order to prevent excessive vibration during operation of the GTE. One solution for facilitating balancing of the rotating assembly includes coupling a band to the rotating assembly. The band may include a system for attaching one or more weights to the band at different radial locations about the band in order to improve the balance of the rotating assembly. However, by virtue of being coupled to the rotating assembly of the GTE, it may be difficult to gain access to the band because the rotating assembly may be located inside an outer case of the GTE.

A method and apparatus for trim balancing a GTE is disclosed in U.S. Pat. No. 5,545,010 issued to Cederwall et al. ("the '010 patent"). In particular, the '010 patent discloses a method and apparatus that allows a GTE to be balanced with the outer case in situ. Access to a rotor of the GTE from the exterior of the outer case is obtained via the intake opening of the compressor air flow path and a pair of holes that may be sealed using a pair of removable plugs. The '010 patent discloses removing the plugs to obtain access to a band coupled to the rotor, such that balancing can be performed by adding or removing weights or plugs to the band.

Although the method and apparatus disclosed in the '010 patent may permit balancing of the rotor, they may suffer from a number of possible drawbacks. For example, the removable plugs may only be accessed via the intake opening of the compressor air flow path. For some GTEs, it may be desirable to provide a band at a location remote from the intake opening. In addition, providing the band at a location of the rotor remote from the rotor vanes and stator vanes of the compressor assembly may add to the length of the GTE. This may be undesirable for a number of reasons. For example, it may be desirable to reduce the footprint of the GTE, thereby rendering it potentially undesirable to add to the length of the compressor section by virtue of providing space for the band.

The methods and systems described in an exemplary manner in the present disclosure may be directed to mitigating or overcoming one or more of the potential drawbacks set forth above.

SUMMARY

In one aspect, the present disclosure includes a method for balancing a rotating assembly of a gas turbine engine. The method includes removing a stator vane from a section of the gas turbine engine, wherein removing the stator vane provides access to a rotating assembly of the gas turbine engine. The method further includes at least one of adding, removing, and repositioning a weight with respect to the rotating assembly via access to the rotating assembly provided by removing the stator vane.

According to another aspect, the disclosure includes a stator vane for a gas turbine engine. The stator vane includes an airfoil configured to direct air and a locator boss coupled to the airfoil and configured to orient the airfoil relative to air flow through the gas turbine engine. The stator vane further includes a stem coupled to the locator boss and extending opposite the airfoil, wherein the stem is configured to facilitate removal of the stator vane from the gas turbine engine.

According to a further aspect, the disclosure includes a gas turbine engine. The gas turbine engine includes an outer case and a compressor section at least partially contained in the outer case. The compressor section includes a plurality of compressor stator vanes and a compressor rotor having a plurality of compressor rotor vanes. The gas turbine engine further includes a combustor section at least partially contained in the outer case. The combustor section is configured to combust compressed air received from the compressor section. The gas turbine engine also includes a turbine section at least partially contained in the outer case. The turbine section includes a plurality of turbine stator vanes and a turbine rotor having a plurality of turbine rotor vanes. At least one of the stator vanes is configured to be removed from the gas turbine engine via a port in the outer case.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic section view of an exemplary embodiment of a GTE;

FIG. **2** is a schematic partial perspective section view of a portion of an exemplary embodiment of a GTE;

FIG. **3** is a schematic partial perspective section view of a portion of an exemplary embodiment of a GTE;

FIG. **4** is a schematic partial perspective exploded view of a portion of an exemplary embodiment of a GTE;

FIG. **5** is a schematic perspective exploded view including an exemplary embodiment of a stator vane;

FIG. **6** is a schematic perspective exploded view including an exemplary embodiment of a stator vane shown from a different angle; and

FIG. **7** is a schematic side view of an exemplary embodiment of a stator vane.

DETAILED DESCRIPTION

FIG. **1** schematically illustrates an exemplary embodiment of a GTE **10**. Exemplary GTE **10** may include an outer case **11** and a compressor section **12**, a combustor section **14**, and a turbine section **16** at least partially contained in outer case **11**. Compressor section **12** is configured to draw air into GTE at A and compress the air before it enters combustor section **14** at B. Compressor section **12** includes stator vanes **18** and a compressor rotor **20** including rotor vanes **20**. Stator vanes **18** and rotor vanes **22** include airfoils, such that as compressor rotor **20** and rotor vanes **22** rotate, air is drawn through compressor section **12**, so that it is compressed and acquires a higher pressure by the time the air enters combustor section **14** at B, thereby increasing the potential energy of the air.

The compressed air from compressor section **12** enters combustor section **14** at B, and fuel may be supplied to combustor section **14** via one or more fuel injector(s) **24**. The fuel and air are ignited at C, thereby causing the air to expand and enter turbine section **16** upon exit from combustor section **14** at D. Turbine section **16** includes stator vanes **26** and a turbine rotor **28** including rotor vanes **30**. Stator vanes **26** and rotor vanes **30** include airfoils and are configured to cause turbine rotor **28** to rotate as the expanding air passes through turbine section **16** at E and exits GTE **10** at F.

GTE **10** may include a shaft **32** coupling compressor rotor **20** and turbine rotor **28** to one another, thereby forming a rotating assembly **33**, which may include one or more of compressor rotor **20**, turbine rotor **28**, and shaft **32**. As turbine rotor **28** is driven by expansion of air through stator vanes **26** and rotor vanes **30**, shaft **32** transfers the rotating power to compressor rotor **20**. As compressor rotor **20** is driven to rotate rotor vanes **22** of compressor section **12**, air is drawn into compressor section **12** at A and compressed as it passes through compressor section **12** and exits at B.

According to some embodiments, turbine rotor **28** may be operably coupled to a load L for performing work in addition to being operably coupled to compressor rotor **20**. For example, turbine rotor **28** may be coupled to a drive shaft **34** and/or a reduction transmission (not shown), which, in turn, may be coupled to load L, which may be used, for example, to supply power to machines, such as, for example, airplanes, locomotives, boats, ships, trucks, automobiles, electric generators, pumps, and/or other machines configured to perform work.

As shown in FIG. **2**, exemplary compressor section **12** includes a compressor stator ring assembly **36** coupled to outer case **11**. Exemplary stator ring assembly **36** may include a radially inner ring **38** and a radially outer ring **40**, between which a plurality of stator vanes **18** extend radially. For example, as shown in FIG. **4**, exemplary stator vanes **18** extend between pairs of apertures **42***a* and **42***b* in inner and outer rings **38** and **40**, respectively.

As shown in FIG. **2**, exemplary compressor rotor **20** includes a hub **44** having a plurality of grooves **46**, each configured to receive a plurality of rotary vanes **22**. For example, exemplary rotary vanes **22** include a root portion **48** configured to couple rotary vanes **22** to hub **44** via one of grooves **46** via coupling methods known to those skilled in the art.

A balancing ring **50** may be associated with rotating assembly **33** at, for example, compressor rotor **20**. Exemplary balancing ring **50** may be either a separate part that is coupled to rotating assembly **33** or formed integrally with a portion of rotating assembly **33**. Balancing ring **50** may be configured to facilitate balancing of rotating assembly **33**. Exemplary balancing ring **50** may be configured to retain removable weights (not shown) at a number of radial locations around balancing ring **50**. For example, as shown in FIG. **2**, balancing ring **50** may include a plurality of apertures **52** located radially about balancing ring **50**. Apertures **52** may be configured to receive one or more balance weights. According to some embodiments, apertures **52** may be internally threaded to engage with threads of a threaded weight, such as, for example, a bolt, screw, or set screw. As explained in more detail below, by adding, removing, and/or repositioning weights relative to balancing ring **50**, the rotating balance of rotating assembly **33** may be improved, which, in turn, may reduce vibration associated with operation of exemplary GTE **10**.

Adjacent rows of stator vanes **18** and rotor vanes **22** form stages of exemplary compressor section **12**. According to some embodiments, for example, as shown in FIG. **1**, balancing ring **50** may be associated with stage **54** that is closest to combustor section **14**. This relatively central location along the length of rotating assembly **33** may result in more effective balancing and/or ease of balancing of rotating assembly **33**. According to some embodiments, balancing ring **50** may be associated with other positions along the length of rotating assembly **33**, such as, for example, on shaft **32** or on turbine rotor **28**. Some embodiments of GTE **10** may include more than one balancing ring located at different positions along the length of rotating assembly **33**.

Referring to FIGS. **2-4**, exemplary GTE **10** may include a stator vane **56** configured to be removed from outer casing **11**. For example, outer casing **11** of exemplary GTE **10** may include one or more ports **58** through which exemplary stator vane **56** may be removed. Exemplary stator vane **56** may serve as one of a plurality of stator vanes **18** associated with stator ring assembly **36**, with stator vane **56** extending through one or more of inner and outer rings **38** and **40**, for example, at a position along the length of GTE **10** associated with balancing ring **50**. In this exemplary configuration, removal of stator vane **56** may facilitate access to balancing ring **50**, so that the rotating balance of rotating assembly **33** may be improved, for example, by adding removing, and/or repositioning weight relative to balancing ring **50**.

As shown in FIG. **4**, exemplary stator vane **56** may be received in relatively enlarged apertures **43***a* and **43***b* of inner and outer rings **38** and **40**, respectively, of stator ring assembly **36**. As shown in FIGS. **2** and **3**, a cap **60** may serve to retain an end of exemplary stator vane **56** and/or close port **58**. According to some embodiments, cap **60** and/or the end of stator vane **56** associated with cap **60** may be configured to provide longitudinal movement of stator vane **56** relative to outer case **11**, which may result from temperature changes and/or gradients during operation of GTE **10**. For example, the end of stator vane **56** associated with cap **60** may include an extension **62** configured to be received in a recess **64** in cap **60**. In the exemplary embodiment shown, cap **60** includes an externally-threaded portion **66** configured to engage internal threads **68** associated with port **58** of outer case **11**.

According to some embodiments, a biasing member **70** such as, for example, a coil spring, may be associated with cap **60** and extension **62** of stator vane **56** in order to bias stator vane **56** in position with respect to stator ring assembly **36**. For example, biasing member **70** may be configured to slide over extension **62**, so that biasing member **70** is positioned between extension **62** of stator vane **56** and recess **64** in cap **60**, for example, as shown in FIG. **3**. According to some embodiments, a ring **72**, which may serve as a washer and/or seal, may be positioned between cap **60** and outer case **11**, for example, in an annular recess **73** in outer case **11**, as shown in FIGS. **3** and **4**.

According to some embodiments, stator vane **56** may include an airfoil **74** configured to direct air within, for example, a portion of compressor section **12**, as shown in FIG. **5**. For example, airfoil **74** may have a curved cross-section (see FIG. **6**), which, in combination with a complimentary airfoil of rotor vanes **18**, serves to compress air drawn through compressor section **12**. Exemplary stator vane **56** may also include a locator boss **76** associated with one end of airfoil **74**. Locator boss **76** may have a cross-section that corresponds to the shape of enlarged aperture **43***b* in outer ring **40** of stator ring assembly **36**. According to some embodiments, the cross-sectional shape of locator boss **76** may be configured to prevent stator vane **56** from being assembled in stator ring assembly **36** in a manner resulting in airfoil **74** being curved in the incorrect direction with respect to other stator vanes **18** in stator ring assembly **36**. For example, locator boss **76** may have an asymmetric cross-section.

Locator boss **76** may include a shoulder **76***a* configured to abut a surface of outer ring **40** of stator ring assembly **36** (see, e.g., FIG. **3**). According to such embodiments, stator vane **56** may be retained between cap **60** and the surface of outer ring **40**, with recess **64** of cap **60** providing longitudinal movement of stator vane **56**. Biasing member **70** may be provided to bias shoulder **76***a* of locator boss **76** against the surface of outer ring **40**.

Stator vane **56** may also include a stem **78** coupled to locator boss **76** opposite airfoil **74**. For example, stem **78** may extend between locator boss **76** and extension **62**. Extension **62** and/or exemplary stem **78** may facilitate removal of stator vane **56** from outer case **11**. For example, extension **62** and/or stem **78** may include a bore **80** (see FIG. **7**) extending longitudinally toward locator boss **76**. Bore **80** may be configured to be engaged by a tool (not shown), such that the tool can extend into port **58** in outer case **11**, engage extension **62** and/or stem **78**, so that stator vane **56** can be withdrawn from outer case **11** via port **58**. For example, bore **80** may be internally threaded, and the tool may include a portion having external threads configured to engage the internal threads of exemplary bore **80**.

At the end of airfoil **74** opposite locator boss **76**, a lug **82** may be provided for receipt in enlarged aperture **43***a* of inner ring **38** of stator ring assembly **36**. For example, lug **82** may have a cross-section corresponding to the shape of enlarged aperture **43***a*. According to some embodiments, the cross-sectional shape of lug **82** may be configured to prevent stator vane **56** from being assembled in stator ring assembly **36** in a manner resulting in airfoil **74** being curved in the incorrect direction with respect to other stator vanes **18** in ring assembly **36**. For example, lug **82** may have an asymmetric cross-section.

According to some embodiments, stator vane **56** may include a projection **84** extending from lug **82** opposite airfoil **74**. Exemplary projection **84** may discourage leakage of air through enlarged aperture **43***a* of inner ring **38** of stator ring assembly **36**. Some embodiments of stator vane **56** do not include a projection **84**.

Exemplary stator vane **56** may be formed from any suitable material. For example, stator vane **56** may be formed from any material that is temperature resistant across a wide range of temperatures, such as a nickel-chromium alloy such as, for example, an alloy marketed under the trade name INCONEL 718. According to some embodiments, stator vane **56** may be formed via machining.

Exemplary stator vane **56** may facilitate balancing of rotating assembly **33** of GTE **10**. For example, exemplary balancing ring **50** may be associated with compressor rotor **20** or turbine rotor **28**, and balancing ring **50** may be configured to permit addition, removal, and/or repositioning of weights with respect to balancing ring **50** to improve the rotating balance of rotating assembly **33**. For example, rotating assembly **33** may be rotated at, for example, a rotating speed representative of operational speeds of GTE **10**, such as, for example, 10,000 rpm. The degree of balance of rotating assembly **33** may be evaluated according to methods known to those skilled in the art. Following such evaluation, weight may be added, removed, and/or repositioned with respect to balancing ring **50** in order to improve the rotating balance of rotating assembly **33**.

To facilitate addition, removal, and/or repositioning of weight with respect to balancing ring **50**, exemplary stator vane **56** may be removed from GTE **10** via port **58**. For example, cap **60** may be removed from port **58** of outer case **11** to gain access to stator vane **56**. Some embodiments of stator vane **56** may include a stem **78** having an internally threaded bore **80**, and stator vane **56** may be removed via port **58** using a tool having an externally threaded portion configured to engage the threads of bore **80**, so that stator vane **56** may be withdrawn from port **58** of outer case **11** with assistance of the tool. After removal of stator vane **56**, access to balancing ring **50** may be gained via enlarged apertures **43***a* and **43***b* in stator ring assembly **36**, thereby permitting addition, removal, and/or repositioning of weights with respect to balancing ring **50**.

Following addition, removal, and/or repositioning of weight with respect to balancing ring **50**, stator vane **56** may be inserted into port **58** and reassembled to stator ring assembly **36**, such that locator boss **76** and lug **82** are positioned in enlarged apertures **43***a* and **43***b* of inner and outer rings **38** and **40**, respectively, of stator ring assembly **36**. Biasing member **70** may be positioned around extension **62** of stator vane **56**, ring **72** may be positioned around port **58**, and cap **60** may be mounted on port **58** of outer case **11**, such that extension **62** extends into recess **64** of cap **60**.

After stator vane **56** has been reassembled in GTE **10**, rotating assembly **33** may be rotated again, and the degree of balance of rotating assembly **33** may be evaluated again according to methods known to those skilled in the art to determine whether rotating assembly **33** is balanced to a desired degree.

INDUSTRIAL APPLICABILITY

Exemplary GTE **10** may be used, for example, to supply power to machines, such as airplanes, locomotives, boats, ships, trucks, automobiles, electric generators, pumps, and/or other machines configured to perform work. For example, operation of GTE **10** may result in rotational power at turbine hub **30**, which may be operably coupled to a load L for performing work (see FIG. **1**). For example, turbine rotor **28** may be coupled to drive shaft **34** and/or a reduction transmission (not shown), which, in turn, may be coupled to load L, which may be used, for example, to supply power to machines.

Exemplary stator vane **56** for GTE **10** may facilitate balancing of rotating assembly **33** of GTE **10**, which may reduce vibration during operation of GTE **10**. For example, exemplary stator vane **56** may be removed from GTE **10** to provide access to balancing ring **50**, even if balancing ring **50** is not positioned in GTE **10** to be accessible via the intake opening of the compressor air flow path. In addition, stator vane **56** may render it possible to provide access to a balancing ring **50** located in a longitudinal portion of GTE **10** associated with stator vanes (i.e., in compressor section **12** or turbine section **16**). Thus, it may be possible to reduce the length of GTE **10** relative to GTEs having a section solely for accommodating a balancing ring. As a result, it may be possible to reduce the footprint of GTE **10**.

It will be apparent to those skilled in the art that various modifications and variations can be made to the exemplary disclosed methods and GTE. Other embodiments will be apparent to those skilled in the art from consideration of the specification and practice of the exemplary disclosed methods and GTE. It is intended that the specification and examples be considered as exemplary only, with a true scope being indicated by the following claims and their equivalents.

What is claimed is:

1. A method for balancing a rotating assembly of a gas turbine engine, the method comprising:

removing a stator vane from a compressor section of the gas turbine engine that is closest to a combustor section, wherein removing the stator vane provides access to a rotating assembly of the gas turbine engine;

at least one of adding, removing, and repositioning a weight with respect to the rotating assembly via access to the rotating assembly provided by removing the stator vane; and

reinserting the stator vane back into the compressor section of the gas turbine engine, wherein reinserting the stator vane includes:

positioning a biasing member around an extension of the stator vane; and

mounting a cap on an outer case of the gas turbine engine, such that the extension extends into a recess of the cap,

wherein removing the stator vane includes engaging internal threads of a bore extending longitudinally within at least one of the extension and a stem of the stator vane.

2. The method of claim **1**, wherein removing the stator vane includes removing the stator vane from a ring assembly including a plurality of stator vanes.

3. The method of claim **1**, wherein removing the stator vane includes withdrawing the stator vane via an opening in the outer case of the gas turbine engine.

4. The method of claim **1**, wherein the at least one of adding, removing, and repositioning a weight with respect to the rotating assembly includes at least one of adding, removing, and repositioning a weight relative to a balancing ring coupled to the rotating assembly.

5. The method of claim **4**, wherein the at least one of adding, removing, and repositioning a weight relative to the rotating assembly includes at least one of adding, removing, and repositioning a threaded member configured to engage threads of the balancing ring.

6. The method of claim **1**, further including rotating the rotating assembly and evaluating a degree of balance of the rotating assembly.

7. The method of claim **6**, further including at least one of adding, removing, and repositioning a weight relative to the rotating assembly based on the degree of balance of the rotating assembly.

8. The method of claim **1**, wherein removing the stator vane includes disengaging the cap from the outer case of the gas turbine engine and exposing an end of the stator vane to facilitate removing the stator vane from the outer case.

9. The method of claim **8**, further including withdrawing the stator vane from the outer case.

10. A stator vane for a gas turbine engine, the stator vane comprising:

an airfoil configured to direct air;

a locator boss coupled to the airfoil and configured to orient the airfoil relative to air flow through the gas turbine engine;

a stem coupled to the locator boss and extending opposite the airfoil, wherein the stem is configured to facilitate removal of the stator vane from a compressor stage of the gas turbine engine closest to a combustor section;

an extension associated with the stem, wherein the extension is configured to cooperate with a cap configured to engage an outer case of the gas turbine engine and couple the stator vane to the gas turbine engine; and

a bore extending longitudinally within at least one of the stem and the extension and having internal threads configured to facilitate removal of the stator vane,

wherein a biasing member is associated with the extension and configured to permit longitudinal movement of the stator vane relative to the cap.

11. The stator vane of claim **10**, wherein the locator boss includes an asymmetric cross-section.

12. The stator vane of claim **10**, wherein the stem includes a threaded surface configured to facilitate removal of the stator vane from the gas turbine engine.

13. The stator vane of claim **10**, further including a lug opposite the airfoil from the locator boss, wherein the lug is configured to orient the airfoil relative to air flow through the gas turbine engine.

14. A gas turbine engine comprising:

an outer case;

a compressor section at least partially contained in the outer case, the compressor section including a plurality of compressor stator vanes and a compressor rotor having a plurality of compressor rotor vanes;

a combustor section at least partially contained in the outer case, the combustor section being configured to combust compressed air received from the compressor section; and

a turbine section at least partially contained in the outer case, the turbine section including a plurality of turbine stator vanes and a turbine rotor having a plurality of turbine rotor vanes,

wherein at least one of the stator vanes is configured to be removed from a compressor stage of the gas turbine engine closest to the combustor section via a port in the outer case, and

wherein the at least one of the stator vanes includes a stem and an extension configured to cooperate with a cap engaging the outer case and coupling the at least one stator vane to the gas turbine engine, wherein a biasing member is associated with the extension and configured to permit longitudinal movement of the at least one stator vane relative to the cap, and

wherein the at least one of the stator vanes includes a bore extending longitudinally within at least one of the stem and the extension and having internal threads configured to facilitate removal of the stator vane.

15. The gas turbine engine of claim **14**, wherein the compressor section includes at least one ring assembly including a plurality of stator vanes, and wherein the at least one ring assembly includes the at least one stator vane configured to be removed from the gas turbine engine via the port in the outer case.

16. The gas turbine engine of claim **15**, wherein the at least one stator vane configured to be removed from the gas turbine engine via the port in the outer case is configured to be removed from the gas turbine engine without removing the at least one ring assembly from the outer case.

17. The gas turbine engine of claim **15**, wherein the compressor section includes a plurality of compressor stages, and wherein the at least one ring assembly is a portion of a compressor stage located closest to the combustion section.

18. The gas turbine engine of claim **17**, further including a balancing ring associated with the compressor rotor, and wherein the at least one ring assembly is located adjacent the balancing ring.

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